

Project Number: EMC-2017-012 – **VERSION #2, January 09, 2018**
Project Name: Assessment of Night-Flying Forest Pest Predator Communities on Demonstration State Forests – with Monitoring across Seral Stages and Silvicultural Prescriptions

Background and Justification:

Bats are the primary predators of night-flying insects, including members of the two taxonomic orders encompassing the most economically destructive forest insect pests, beetles (Coleoptera) and moths (Lepidoptera). Among the 17 insectivorous bat species known to inhabit forests in California (Pierson and Rainey 2007) are at least ten species that prey primarily on insects within these two insect orders (Lacki et al. 2007a, others). While none of these species are currently listed under the state or federal endangered species acts, four species are considered ‘species of special concern’ (SSC) by the California Department of Fish and Wildlife (CDFW), three additional species have been proposed to be CDFW SSC. The California State Wildlife Action Plan (CDFW 2015) lists five of these seven species as ‘species of greatest conservation need’. Seven of the 17 forest bat species in California are considered ‘special concern’ species by the US Fish and Wildlife Service (CDFW 2017) and three species are considered ‘sensitive’ by the US Forest Service (CDFW 2017). Additionally, the Western Bat Working Group considers 11 of the 17 forest bat species in California to be of high (7 species) or medium (4 species) levels of concern warranting “the highest priority for funding, planning, and conservation action” and “closer evaluation, more research, and conservation actions of both the species and the possible threats”, respectively. Because the annual economic value of bats as predators of agricultural crop pests in the US has been shown to range from \$12 to \$173/acre (Cleveland et al. 2006), it is likely that bats provide valuable ecological services to the forest industry in the US. Studies designed to provide baseline data on the relative abundance of bat species among Demonstration State Forests (DSFs), seral stages, and silvicultural prescriptions can serve as the first step in the broader study of management approaches and resultant habitat conditions that promote healthy communities of night-flying forest pest predators.

Literature Review

Differences in Bat Communities among Seral Stages

One of the first published works using bat echolocation detection monitoring (Thomas 1988) was followed by several studies assessing bat activity levels among forest stand age classes and seven such studies published between 1988 and 1999 are summarized by Hayes and Loeb (2007). This review excludes studies that compared cut stands to adjacent uncut stands immediately after harvest, as such comparisons can be expected to result in extreme differences in both overall and within species activity levels. Hayes and Loeb (2007) note that bats are not thought to respond directly to stand age, but rather to associated structural characteristics of forest stands and to broader spatial forest stand contexts. Hayes and Loeb (2007) identify the primary drivers of these phenomena as availability and distribution of roosts, vegetative clutter within the available flight space, and prey availability - and caution that the distinction between stand age and stand structure, as influenced by stand history, silviculture, and past retention of legacy structures (Guldin et al. 2007) are important factors.

Most, though not all, studies show heavy use by bats of more ‘open’, less ‘cluttered’, habitats (Brigham et al. 1992, Erickson 1993, Erickson and West 1996, Krusic et al. 1996, Grindal and Brigham 1998, Menzel et al. 2001, Patriquin and Barclay 2003), even half-acre patch cuts (Grindal and Brigham 1998, Tibbels and Kurta 2003), likely due to reduced vegetative clutter and/or increased insect abundance (Hayes and Loeb 2007). However, some species (e.g., northern myotis, *Myotis septentrionalis*) appear to avoid large openings while using smaller gaps extensively (Owen et al. 2003). Higher bat activity in older forests than in young forests has been shown (Thomas 1988, Perkins and Cross 1988, Thomas and West 1991, Krusic et al. 1996, Crampton and Barclay 1998, Grindal and Brigham 1999, Humes et al. 1999, Jung et al. 1999) and is

frequently noted as likely due to higher availability of snag roosts in older stands (Perkins and Cross 1988; Thomas 1988; Thomas and West 1991; Crampton and Barclay 1996, 1998; Humes et al. 1999; Kalcounis et al. 1999). Increased vertical complexity in older stands and associated opportunities for bats to partition foraging space is often cited to explain greater use of older stands (Hayes and Gruver 2000, Hayes and Loeb 2007).

Bat activity in upland coniferous forests between 10 and 100 years old has been shown to be low relative to both younger and older forests (Thomas 1988, Thomas and West 1991, Erickson and West 1996, Krusic et al. 1996, Parker et al. 1996, Crampton and Barclay 1998, Jung et al. 1999, Tibbels and Kurta 2003). Hayes and Loeb (2007) suggest that this phenomenon results from increased vegetative clutter and reduced availability of roost sites in young, dense forest stands. Forest type and composition, though confounded with forest structure, appear to have significant influence on bat activity levels in some studies and this phenomenon could be driven by differences in both roost and prey availability (Krusic et al. 1996, Kalcounis et al. 1999, Patriquin and Barclay 2003).

Although forest fragmentation has been shown to negatively impact bat activity in other regions (e.g., Law et al. 1999 and Pavey 1998 in Australia, Estrada and Coates-Estrada 2002 and Schulze et al. 2000 in Mexico and Central America), landscape-level influences of forest management on bats has been poorly studied in the United States and Canada (Hayes and Loeb 2007). The only published study of greater than local scale found no significant effect (Erickson and West 2003), although sampling was limited to stands of mature conifers on public lands and only 100 hectares surrounding these stands (Hayes and Loeb 2007).

Differences in Bat Communities among Silvicultural Systems

Several studies of bat response, based on activity, to silvicultural treatments in North America have been recently summarized and show major gaps in our understanding in this area, and this is particularly true relative to monitoring bat community changes over longer temporal scales (Law et al. 2016).

Even-aged Systems

Studies of bat activity relative to even-aged silvicultural systems in North America have focused primarily on clearcutting (i.e., 10 studies, summarized below), though some studies of two-age systems (e.g., seed tree, shelterwood, and deferment harvests) are available (Owen et al. 2004, Tichenell et al. 2011, Dodd et al. 2012). Responses in bat activity to clearcutting are varied, including no response for little brown myotis (*M. lucifugus*; Lunde and Harestad 1986), silver-haired bats (*Lasionycteris noctivagans*; Hogberg et al. 2002), and the *Myotis* spp. community; Owen et al. 2004) and decreased activity for eastern red bats (*Lasiurus borealis*; Hart et al. 1993, the *Myotis* spp. community; Hart et al. 1993, Hayes and Adam 1996), northern myotis (Patriquin and Barclay 2003), and for multiple species (Parker et al. 1996).

Increased bat activity in clearcut areas has been shown for hoary bats (*L. cinereus*; Hart et al. 1993, Owen et al. 2004), big brown bats (*Eptesicus fuscus*; Erickson and West 1996, Tichenell et al. 2011), silver-haired bats (Erickson and West 1996, Patriquin and Barclay 2003, Owen et al. 2004, Tichenell et al. 2011), Townsend's big-eared bats (*Corynorhinus townsendii*, Erickson and West 1996), little brown myotis (Hogberg et al. 2002, Patriquin and Barclay 2003), northern myotis (Hogberg et al. 2002), red bats (Tichenell et al. 2011), and for multiple species (Dodd et al. 2012). Studies also found mixed results (i.e., both increases and decreases in bat activity) for multiple species (Grindal 1996, Swystun et al. 2001).

Uneven-aged Systems

Studies of bat activity relative to uneven-aged silvicultural systems in North America are less numerous and results have been less varied. Treatments including group selection (n = 3), small cut blocks (n = 1), canopy gaps (n = 1), thinning (n = 4), and salvage logging (n = 1) have mostly resulted in increased bat activity for multiple species (Erickson and West 1996, Krusic et al. 1996, Perdue and Steventon 1996, Grindal and

Brigham 1998, Humes et al. 1999, Menzel et al. 2002, Hayes 2009) and for big brown and red bats (Ford et al. 2005, Loeb and Waldrop 2008), though no difference in bat activity was noted for two studies (Patriquin and Barclay 2003, Tibbels and Kurta 2003) and for tri-colored bats (*Perimyotis subflavus*, Loeb and Waldrop 2008) and a decrease in bat activity was shown for *Myotis* spp. in one study (Ford et al. 2005).

Mixed results among studies and bat species is not unexpected and are likely due to differences among specific treatment characteristics (e.g., size of openings, stand species composition, and age since harvest, etc.; Hayes and Loeb 2007) and to differences in morphology associated with foraging niches among bat species (Norberg 1981, Norberg and Raynor 1987, and others cited in Lacki et al. 2007b). Despite complicating factors, the combined results of the reviewed studies suggest that short-term, stand level manipulation of forest habitat differentially impacts bat species' activity levels over larger temporal and spatial scales. However, studies directly examining longer-term impacts of forest habitat manipulation to bat activity are far less common in the literature. Further, only 7 of the 21 studies of seral stages, and six of the 21 studies of silvicultural systems, cited in review above were conducted in western North America.

Proposed Study

Knowledge of bat community composition among demonstration state forests (DSFs), seral stages, and silvicultural prescriptions is prerequisite to broader study of ecological dynamics among forest bats, forest pests, and forest management. The proposed study will be observational and include replication within study areas. Data resulting from this study will serve as baseline monitoring, provide information relevant to effectiveness monitoring, and will provide the equipment required for future trend monitoring. Proposed use of the Jackson (Mendocino County), Latour (Shasta County), Mountain Home (Tulare County), and Soquel (Santa Cruz County) DSFs as study areas will allow for local (within DSF) and wider geographic scales of inference and four sampling seasons will be an appropriate temporal scale for study objectives. Management plans for each of the five California DSFs larger than 1,000 acres (CAL FIRE 2008, 2010, 2013, 2016a, 2016b) have chapters on historic, existing, and future priority research topics. Each plan has addressed wildlife research within these categories and none of these DSFs have hosted historic or current forest bat research projects (CAL FIRE 2008, 2010, 2013, 2016a, 2016b). Although lists of species likely to occur on some DSFs have been developed from species ranges and habitat preferences, no locally collected baseline data regarding the bat species present on these DSFs is currently available.

The proposed applied research is designed to elucidate relationships among bats and habitats beyond short-term effects by sampling from sites resulting from older forest habitat manipulation within the context of management of forests for timber products in western North American forests. To reduce noted complicating factors, only interior locations within forest blocks of interest will be acoustically sampled for bat activity levels and forest insect communities will be sampled among habitats of interest.

Acoustic Detection

The proposed study will be conducted on one DSF per year with nightly dusk through dawn sampling for a full spring through fall acoustic sampling season at upland sites $\geq 100\text{m}$ from bat travel corridors within late-seral, ($n = 4$) and mid-rotation age ($n = 4$) stands. Within each seral stage, sampling sites will be divided evenly between regeneration from even-aged ($n = 4$) and uneven-aged ($n = 4$) silvicultural systems. SongMeter 4 acoustic detection units (SM4BAT) with ultrasonic microphones (Wildlife Acoustics, Maynard, Massachusetts) will be attached to trees by bungee cords approximately 1.4m above the ground. Detector microphones will be attached to 10m extendable poles and raised into canopy gaps to maximize the quality of recordings. Bat activity will be recorded in full-spectrum files and stored on compact flash data cards. Data cards and batteries will be swapped-out approximately every 30 days. Existing stand-level forest inventory data will be used to inform placement of acoustic sampling detectors within stands of interest. Other available stand data will be used in bat activity relative to day roost structure availability.

Bat Capture Efforts and Insect Trapping

To supplement acoustic sampling of foraging bats with in-the-hand species identification, bat capture efforts will be conducted with mist nets near ponds or along bat travel corridors (e.g., streams, roads, trails) and $\geq 100\text{m}$ from acoustic stations, during at least 2 nights each month. Insect trapping at each acoustic detection site will be conducted during capture nights to sample prey availability. In a manner similar to that employed by Johnson et al. (2017), 10-W black light traps (Bioquip Products, Ranch Dominguez, California) will be suspended at approximately 2.5m above the ground and operated from dusk to dawn. A dichlorvos-based “pest strip” (approximately 2 x 6cm) will be placed inside each black-light trap to subdue captured specimens. Bat and insect capture sessions will be conducted concurrent with monthly acoustic station maintenance trips and likely supplemented by potential additional efforts as collaborators’ schedules allow.

Habitat Data

Existing stand-level forest inventory data will be used to characterize the vicinity of each acoustic detection system and other stand data, e.g., including abundance of snags and hollow trees, favored as day roosts by Myotine bats, will be used to assess potential differences in bat activity relative to day roost structure availability.

Labor Needs

While the proposed field work could be physically accomplished by the Principle Investigator alone, collaboration with several interested CAL FIRE and CDFW personnel with the field, lab, and office work is welcomed, has been offered, and is anticipated.

Data Analyses

Full spectrum acoustic data will be analyzed with SonoBat call analysis software (version 4, California region, SonoBat, Arcata, California) in a manner similar to that employed by Johnson et al. (2017). Relative overall bat activity, activity within species groupings (to minimize the probability of misidentification; Russo and Voigt 2016), and activity within species that can be reliably identified by SonoBat will be tested among habitat categories with a two-way analysis of variance (Sokal and Rohlf 1995) within each SDF. Tukey’s Honestly Significant Difference means separation procedure will be used to evaluate effects in significant models (Zar 1999). Canonical correspondence analysis (CCA) will be used to assess relationships between bat activity and forest structure across all four study areas (Lattin et al. 2003) and the development of information-theoretic models (Burnham and Anderson 2002) of the stand characteristics that contribute most to presence or absence of various bat species or species groupings may also be explored with the full four-year dataset.

Response variables will include overall bat activity, activity for individual species that can be reliably identified to the species level, and activity within species groupings. Species groupings will include high, medium, or low frequency Myotines (i.e., minimum call frequency above 45 kHz, 35 to 40 kHz, or below 30kHz, respectively), non-Myotines (i.e., big brown, silver-haired, or hoary bats). Among the Myotine groupings, the high frequency group includes Yuma and California myotis (*M. yumanensis* and *M. californicus*, respectively); the mid frequency group includes little brown, western small-footed, and long-legged myotis (*M. lucifugus*, *M. ciliolabrum*, and *M. volans*, respectively); and the low frequency group includes western long-eared and fringed myotis (*M. evois* and *M. thysanodes*, respectively). The non-Myotine group includes the Lasiurines (i.e., silver-haired, hoary, and western red (*Lasiurus blossevillei*) bats) and big brown bats. Some calls of some of the aforementioned species may be determined to be reliably identified by SonoBat through combined automated and manual verification techniques. Calls of additional species that may occur on our study areas (Baker et al. 2008, others) and are known to be reliably identified

by SonoBat include Townsend's big-eared and pallid bats (*Corynorhinus townsendii* and *Antrozous pallidus*, respectively). Species level analyses will be conducted only for those species that can be reliably identified to the species level with manual call verification techniques.

Bat capture data will be analyzed and discussed in narrative form and tests for differences among capture sites may be conducted if sites can be classified as existing within distinctly different habitats that are of interest to DSF managers. Insect capture data will be analyzed in a manner similar to that employed by Dodd et al. (2012). Captured insects will be identified to the lowest taxon practical using available keys (Triplehorn and Johnson 2005, others) and university reference collections (if available). Insect data will be partitioned by taxon and tested for differences among habitat categories with a two-way analysis of variance (Sokal and Rohlf 1995) within each SDF. Tukey's Honestly Significant Difference means separation procedure will be used to evaluate effects in significant models (Zar 1999). Canonical correspondence analysis (CCA) will be used to assess relationships between insect availability and forest structure across all four study areas (Lattin et al. 2003) and the development of information-theoretic models (Burnham and Anderson 2002) of the stand characteristics that contribute most to presence or absence of various insect taxon or taxon groupings may also be explored with the full four-year dataset.

Potential Future Research Enabled by the Proposed Study

The proposed study represents an opportunity for the California DSF system to contribute to our collective knowledge of forest bat community presence and responses to longer-term responses to habitats resulting from even-aged and variable retention silvicultural systems in both mid-rotation and late seral stages. The equipment purchased for the proposed study can be used to support an ongoing forest bat research program without additional investment beyond principle investigator salary and travel costs for field work and analyses. One such study is examination of the 5 to 10 year periodic effects of post-fire salvage and regeneration treatments on Boggs SDF, by using stands currently supporting erosion and bird community studies.

Objective(s) and Scope:

This study seeks to determine the relative abundance of bat species among DSFs, seral stages, and silvicultural prescriptions as the first step in the broader study of management approaches and resultant habitat conditions that promote healthy communities of night-flying forest pest predators. While this objective is appropriately narrow in scope for a baseline and short-term effectiveness monitoring study, future related studies could include longer-term effectiveness and trend monitoring that could be expanded across additional study areas and forest habitat designations.

Monitoring Question:

1. Are the FPRs and associated regulations effective in promoting habitats suitable to forest bat communities that prey on forest insects within the taxonomic orders Coleoptera and Lepidoptera?

FPRs and Regulations:

14 CCR § 897; 14 CCR § 912.9 (932.9, 952.9); 14 CCR § 913.4 (939.4, 959.4); and 14 CCR § 919 (939, 959).

EMC Critical Questions or Priorities:

Theme 7: Wildlife Habitat: Species and Nest Sites (*i.e.*, species presence among DSFs).

Theme 8: Wildlife Habitat: Seral Stages (*i.e.*, species presence across seral stages/silvicultural prescriptions).

Theme 10: Wildlife Habitat: Structures (*i.e.*, species presence, indicative of roost structure availability).

Collaborators:

The California Department of Forestry and Fire Protection (CAL FIRE), the California Department of Fish and Wildlife, and possibly other California natural resource agencies and California universities.

Existing and Needed Funding:

Existing funding for Principle Investigator salary and travel will be provided by CAL FIRE and no Board of Forestry funding will be applied to overhead. Board of Forestry funding of approximately \$20,000 is needed for eight (8) bat ultrasonic acoustic detection units (~ \$10,000), species identification data analysis software (~ \$2,000), eight (8) 30-meter extendable poles (~\$1,000), bat capture equipment (~ \$3,000), eight (8) black light traps for night-flying insects (~ \$3,000), and ~\$1,000 for miscellaneous supplies, e.g., nitrile gloves, disposable bat holding bags, batteries, data cards, etc. The equipment required for this study consists of durable goods that can be invaluable to related future applied forest bat research, including long-term effectiveness and trend monitoring, bat diet, and bat roost structure use studies of forest bats within the context of forest management in California.

Timeline and Fiscal Year(s):

Deployment of bat acoustic detectors and associated bat capture sessions will begin in May of 2018, be conducted between the months of May and October, and continue through October of 2021. Data analyses will occur each winter and annual reports will be produced. Presentations or posters at local, state, or regional meetings will be used to communicate study progress to interested groups. A manuscript detailing the project design, methods, results, discussion, and conclusions may be developed and submitted to pertinent peer-reviewed journals, with review and permission from the Effectiveness Monitoring Committee, Board of Forestry, and the collaborators' Departments within the Natural Resources Agency following the end of the four-year study.

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Submitted by Michael Baker, CAL FIRE, 1/9/2018

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